N90-28270

in: Proceedings of the FIRE Science Meeting, Monterey, CA, 227-231 (1989)

IMPACT OF CIRRUS ON THE SURFACE RADIATIVE ENVIRONMENT AT THE FIRE ETLA PALISADES, NY SITE*

David A. Robinson
Department of Geography
Rutgers University
New Brunswick, NJ 08903

George Kukla and Allan Frei
Lamont-Doherty Geological Observatory of Columbia University
Palisades, NY 10964

1. INTRODUCTION

FIRE Extended Time Limited Area (ETLA) observations provide year-round information critical to gaining a better understanding of cloud/climate interactions. The Lamont/Rutgers team has participated in the ETLA program through the collection and analysis of shortwave and longwave downwelling irradiances at Palisades, NY. These data are providing useful information on surface radiative fluxes with respect to sky condition, solar zenith angle and season. Their utility extends to the calibration and validation of cloud/radiative models and satellite cloud and radiative retrievals. Here, the impact cirrus clouds have on the surface radiative environment is examined using Palisades ETLA information on atmospheric transmissivities and downwelling longwave fluxes for winter and summer cirrus and clear sky episodes in 1987.

2. MEASUREMENT PROGRAM

Downwelling hemispheric shortwave (SW: 0.28-2.8μm) and longwave (LW: 4.0-50.0μm) irradiances have been measured at Palisades, NY since December 1986. Observations are made with an Eppley Precision Spectral Pyranometer and an Eppley Pyrgeometer which were calibrated with Colorado State University instruments during the Cirrus IFO in October 1986, and have since been periodically recalibrated by the Eppley Laboratory. Pyrgeometer output contains an adjustment for body temperature but not for dome temperature. Data are transmitted to a Campbell CR-21 Digital Recorder, where one minute averages of ten second samples are stored and subsequently dumped to a cassette recorder. Using a Campbell C-20 Cassette Interface, these data are transferred to an Apple Macintosh computer for analysis and archiving. In addition to the full shortwave and longwave irradiances, hemispheric near infrared irradiance (NIR: 0.7-2.8μm) and diffuse components of the SW and NIR fluxes have also been measured for all or part of the past two and one half years.

Among the variables generated from the measured data is shortwave atmospheric transmissivity, which is simply the ratio of downwelling SW at the surface to incoming SW at the top of the atmosphere. Between 0.28-2.8μm, the latter is equal to 0.971 times the solar constant of 1366.97 W/m^2.

Palisades, NY (41°00' N, 74°55' W) is situated approximately 10 km north of the northern limits of New York City. The radiometers are mounted on the roof of a two story building approximately 130 meters above sea level. A daily log of sky conditions is maintained and fisheye (180°) sky photos are taken periodically coincident with overpassing NOAA 9 and Landsat satellites.

* This work is supported by NASA grant NAG-1-653.

3. EXPERIMENT DESIGN

The success of a comparative analysis such as this strongly depends on the selection of appropriate regional cirrus and clear episodes. In the present study, this involved interrogating detailed meteorological observations from NOAA first-order observation sites at Newark and LaGuardia Airports along with the more qualitative Palisades sky log. Palisades is situated 25 km north-northwest of LaGuardia and 40 km north-northeast of Newark. Airport observations of cloud type, percent total and percent opaque cloud cover, altitude of visible cloud bases and horizontal visibility were available digitally at three-hour intervals. Data were obtained from the National Climatic Data Center.

An interactive data management system was developed to extract intervals of cirrus and clear skies meeting specified criteria from the airport data files. To insure a regional nature to any interval selected, the criteria had to simultaneously be met at LaGuardia and Newark and be in agreement with the Palisades sky observations. Cirrus criteria included: 1) solar zenith angle (SZA) less than 80° (data quality diminishes greatly at higher SZAs due to pyranometer design and the presence of groves of trees near the horizon), 2) a full, broken or scattered cloud cover with bases of 6100 m (20000 ft) or higher, 3) no other clouds present, 4) horizontal visibility greater than 16 km (10 miles). Clear criteria included: 1) SZA less than 80°, 2) no clouds present and 3) visibility greater than 16 km. The visibility specification was made to reduce the influence of water vapor or dust in the lower troposphere on downwelling irradiance, thus, as much as possible, isolating the impact cirrus have on surface fluxes. Cirrus and clear episodes of at least three hours duration (eg. including at least two consecutive airport observations) from the winter (Jan., Feb., Dec.) and summer (Jun., Jul., Aug.) of 1987 were analyzed.

The study region sky is rarely reported to be completely covered with cirrus with no other clouds present. When cirrus are alone their coverage is normally observed to be broken (.6-.9) or scattered (.1-.5). For instance, in all of 1987 only 18 of the four daytime three hourly reports at Newark and 5 at LaGuardia noted overcast (1.0) cirrus with no other clouds present when visibility exceeded 16 km. This is partly due to the physical nature of cirrus clouds, but also appears to result from the subjective task of defining just when or where a cirrus cloud begins or ends; no doubt observers often miss subresolution cirrus. As the goal is to better understand cirrus impacts on the surface radiative environment, it is important to investigate these natural cirrus episodes, rather than the few cases when an easily observed cirrus overcast is present.

4. RESULTS

In 1987, some 46 winter hours met the cirrus criteria and 75 hours met clear specifications (fig. 1). The criteria were met less frequently in the summer of 1987, with 25 hours of cirrus and 36 hours of clear skies observed. The summer minimum was partly due to the limitations imposed by the visibility criterion

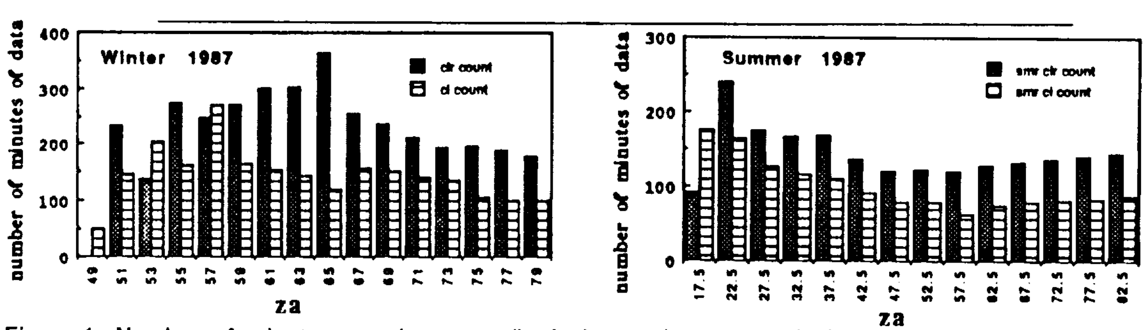

Figure 1. Number of minutes meeting prescribed cirrus (cl count) and clear (clr count) criteria in the winter (left) and summer (right) of 1987. Information is segregated by solar zenith angle (za) in 2° (winter) or 5° (summer) increments.

a) Shortwave transmissivity

Transmissivities for cirrus and clear episodes in winter and summer and seasonal values within each sky category were compared. All results were segregated according to zenith angle due to the impact SZA has on surface fluxes. For instance, in both seasons clear and cirrus transmissivities increased approximately 0.18 as the SZA decreased from 80° to 50°. This increase continued in summer as mid-day SZAs fell to 18°, however the rate from 50° to 18° was about half that found at higher SZAs. These curves roughly parallel atmospheric path lengths which vary from 5.8 at 80° to 1.6 at 50° to 1.1 at 20°.

Transmissivities during winter cirrus episodes were approximately 0.03 lower than clear-sky values (fig. 2). Cirrus values had a range of 0.05-0.10 within ±1 standard deviation (SD) of the mean as compared with a 0.02-0.04 range with clear skies. The +1 SD transmissivities were similar for both cirrus and clear episodes. This is probably due to the presence of relatively clear skies between discontinuous cirrus.

Summer transmissivities during cirrus episodes ran some 0.01 to 0.08 lower than clear-sky values at zenith angles between 15° and 80° (fig. 2). On average, it appears that the difference is close to the 0.03 seen in winter, with the range in means primarily a function of the small cirrus sample.

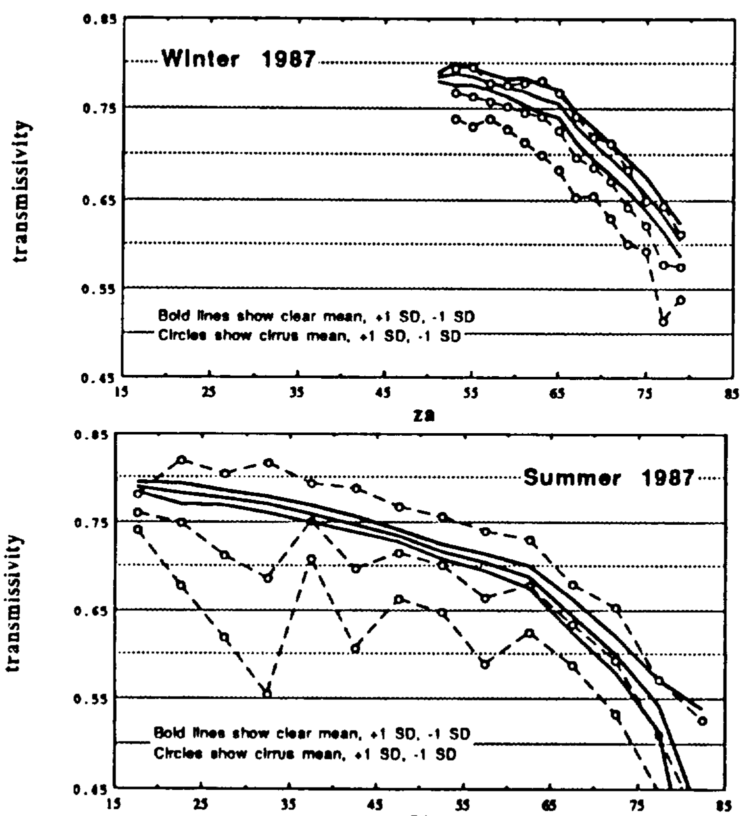

Figure 2. Transmissivities with cirrus and clear skies present in winter (top) and summer (bottom). Data are plotted by solar zenith angle (za).

ORIGINAL PAGE IS OF POOR QUALITY

During cirrus episodes, winter transmissivities at a given zenith angle were approximately 0.06-0.07 larger than summer values (fig. 3). Differences approached 0.10 when skies were clear (fig. 3). Seasonal differences may be a function of the several times greater amount of water vapor found in the summer atmosphere. Increased atmospheric dust and pollutants in a generally more stable atmosphere may also contribute to lower summer transmissivities. Again, it is worth emphasizing that this study minimized the effects of lower tropospheric moisture and turbidity by only considering episodes where horizontal visibility at the surface exceeded 16 km.

Coincidentally, winter and summer mid-day transmissivities under cirrus (0.76) and clear (0.79) skies were almost identical, despite roughly a 30° difference in SZA. This is at least partly a result of the seasonal differences in atmospheric composition.

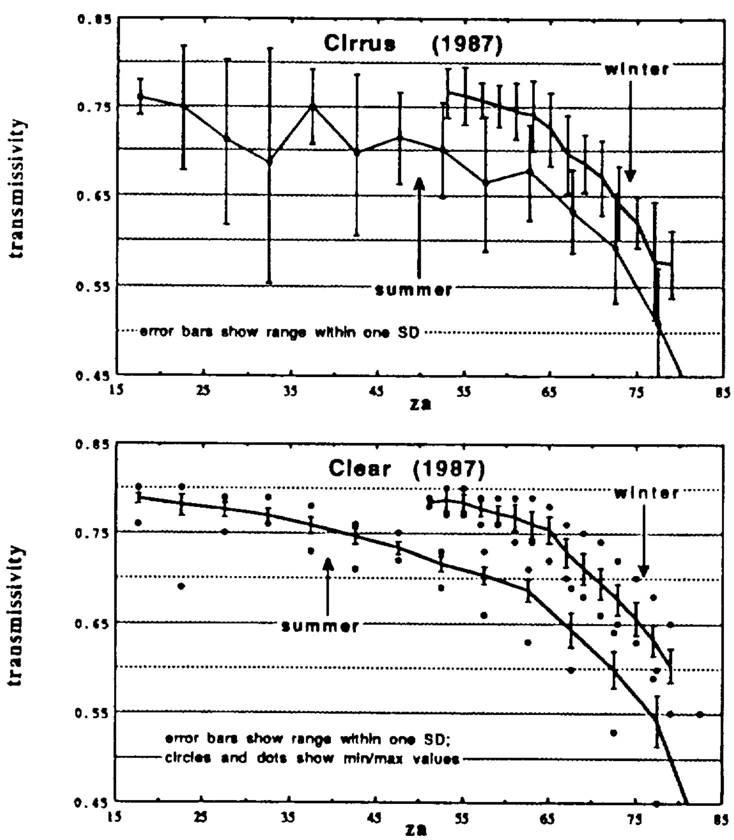

Figure 3. Summer versus winter transmissivities with cirrus (top) or clear (bottom) skies present. Data are plotted by solar zenith angle (za).

b) Downwelling longwave irradiance

Winter longwave irradiance with cirrus present was approximately 210 W/m^2 (fig. 4). This was some 30 W/m^2 higher than clear-sky values, In fact the -1 SD value for cirrus skies consistently exceeded the clear mean. Cirrus/clear differences of only about 15 W/m^2 were noted in summer (fig. 4). The clear mean and +1 SD values often fell between the cirrus mean and -1 SD cirrus values.

Longwave irradiance exhibited zenith angle dependence in the summer, increasing from 315 to 380 W/m^2 between SZAs of 80^o and 20^o in cirrus cases and 305-350 W/m^2 when skies were clear. Dome heating may have been responsible for a portion of the diurnal trend. The remainder may have been due to atmospheric temperature fluctuations. Evidence for the latter includes: 1) morning irradiances were consistently below afternoon readings at similar zenith angles, 2) cirrus irradiances increased more with decreasing SZA than clear values and 3) little SZA dependence was noted in the winter.

Interseasonal longwave values for cirrus and clear skies illustrate the warmer summer atmosphere. Irradiances were approximately 120 W/m^2 higher in summer than in winter during cirrus episodes and about 140 W/m^2 higher for clear skies.

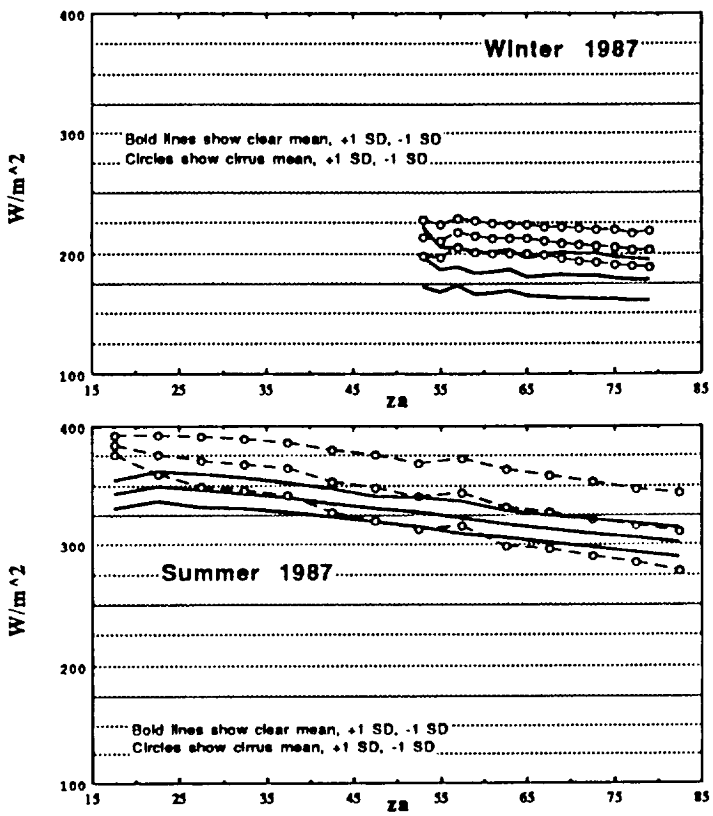

Figure 4. Downwelling longwave irradiance with cirrus and clear skies in winter (top) and summer (bottom). Data from 1987 daylight hours are plotted by solar zenith angle.

5. CONCLUSION

A limited data set gathered in 1987 at the Palisades, NY FIRE ETLA site suggests that cirrus have a larger impact on the surface radiative environment in winter than in summer. The presence of cirrus clouds in both seasons resulted in a decrease in atmospheric transmissivity of approximately 0.03 over clear skies. Downwelling longwave irradiances were about 30 W/m^2 higher for winter cirrus episodes and 15 W/m^2 higher in summer cases compared with clear-sky episodes. Data continue to be gathered at Palisades to refine these analyses and to expand the study by incorporating data on spectral and directional components of incoming shortwave fluxes and on the net radiation balance.